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Student performance variables under automated, conventional, and a combination of automated and conventional conditions of instruction were investigated. Recommendations for the integration of programed material into the classroom were sought.

Three groups of junior college students were used in the experiment. The groups were chosen at random. One group had twice as much instruction time per week; this instruction was evenly divided between lectures and programed material. Another group had only lectures; the third group had only programed material. Criterion tests, psychological tests, and an interview were used for evaluating achievement.

The group that received lectures and programed instruction showed the greatest achievement. The other two groups showed about equal achievement. Differences in progress rates were attributed to personality differences. There was no evidence of time saving with the programed materials. Test results were presented in two tables.

A bibliography and an appendix of student attitudes toward teaching machines were included.

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PROGRAMMED LEARNING:

A COMPARATIVE EVALUATION OF STUDENT PERFORMANCE VARIABLES UNDER COMBINATIONS OF CONVENTIONAL AND AUTOMATED INSTRUCTION*

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and

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U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
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PROGRAMMED LEARNING: A COMPARATIVE EVALUATION OF STUDENT PERFORMANCE VARIABLES UNDER COMBINATIONS OF CONVENTIONAL AND AUTOMATED INSTRUCTION

Richard S. Hatch[1] and Lanning L. Flint[2]

Numerous articles dealing with "teaching machines" or, more appropriately, programmed learning have appeared in various educational and psychological journals (Carr, 1959; Coulson and Silberman, 1960; Crowder, 1959; Mager, 1959; Rath, and Anderson, 1958; Skinner, 1954). In the main, these articles report (1) experts' opinions as to the contributions expected from applications of self-instructional materials, or (2) results of small scale "laboratory" experiments with short programs administered to volunteer or other specially selected subjects. Full scale classroom applications largely await the appearance of expensively prepared and extensively revised programs; however, a small number of these longer programs are presently available. Evaluations of complete curriculum programs carried out over extended periods in the classroom will have to be undertaken before a comprehensive understanding of programmed learning as an applied technology can exist.

Among the few comparative studies that have been conducted in a school environment, Raab (1961), in his Master's thesis, reported the results of the first of a two-semester evaluation of several TEMAC high school mathematics programs in the San Francisco Unified School District. In general, the results are uninterpretable, as (1) subjects were not randomized, and (2) statistically significant differences on intelligence measures existed between the experimental and control groups.

Several studies (Holt and Hammock, 1961; Crowder and Zachert, 1960) involving longer programs have been conducted in industrial and military settings; however, the writers believe the training objectives, as well as various student-institution relationships, differed substantially in the above studies from those encountered in the junior college environment investigated in the study reported below.

The major purpose of this study was to investigate student performance variables under automated, conventional and a combination of automated and conventional conditions of instruction. Learning associated with the several instructional approaches was evaluated over a

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2. Lanning L. Flint, an electronics instructor at Bakersfield College, was Project Director for this NDEA-supported study.

longer period of time than that typically employed, heretofore, by researchers contributing to the literature on automated instruction.

The authors believe that programmed materials present, as yet, unresolved problems to school authorities, and the solutions to these problems are unlikely to emerge from studies using volunteer students exposed to a relatively small number of hours of programmed material. Consequently, a second purpose of this study was to arrive at recommendations for integrating programmed materials into the classroom. The recommendations emerging from the study will be reported elsewhere (Collins, 1962). Generally, these recommendations derive from the "experience" gained in the study as opposed to the statistical evidence analyzed and reported in this paper.

EXPERIMENTAL PROCEDURES

Treatment Conditions: Three experimental groups were used:

(1) The Optimal group received the complete course via three hours per week of conventional instruction and three hours per week of programmed instruction on the teaching machine.

(2) The Machine group received the course in three hours per week of programmed instruction on the teaching machine only.

(3) The Lecture group received the course via three hours per week of lecture instruction only.

All groups received three hours of laboratory instruction per week, and all groups received identicial assignments from the textbook (reading, problems, etc.). Only one lecture section existed for the course, so that those subjects assigned to lecture instruction met together and received identical lecture presentations.

Each student assigned to either the Optimal or Machine group was permitted to schedule three hours per week of machine instruction; however, failure to report for a machine session in any particular week was permitted if the session was "made up" during some other week. Students could also report for as many additional hours of programmed instruction as desired, providing machine time was available. A complete record of hours of exposure to both lectures and machines was maintained for all subjects.

Selection of Subjects: The following procedures were followed to insure random assignment of students to treatment conditions: (1) Prior to registration, the order in which students would register for first semester electronics was randomized into three groups; (2) the students, upon presenting themselves for registration, automatically received an order of

registration assignment to one of the three experimental conditions; (3) the counselor advised each student as to the instructional grouping into which he had fallen and planned his class schedule to meet the demands of the experiment. No students were allowed to alter the randomized assignments; nor did any student refuse to participate in the study. These procedures assured randomization of such variables as intelligence, motivation, interest in electronics, academic history, etc., across treatment conditions.

Description of Self-Instructional Materials: The teaching machine used was the AutoTutor* Mark II, a semi-random access 35mm film projecting device. A branching or intrinsic program (Crowder, 1960), "First Year Electronics", was evaluated.[1] Intrinsic programs utilize multiple-choice responses and "branch" to corrective or remedial frames as a function of student response accuracy. In addition, these programs provide automatic evaluation of student mastery over each hour or so of material through the use of test sequences designed to "wash" students back over sections of the program.

The unique characteristic of this device, as compared to devices which display programs and store "tamper-proof" records, is the use of light-dependent resistors to read a coding on the microfilm. This permits an interlocking of the programmed material with the keyboard. Specific control of student response behavior occurs at each frame, and, if the device is used with the lid locked, it is possible to prevent advancement of the program (through "cheating" or unmotivated student response behavior) past various test points.

Without a special recorder attachment, the device does not maintain a frame-by-frame record of student responses, but does record, by means of a Veeder Root counter, the total errors associated with a given period of exposure. Therefore, the records maintained for each student receiving programmed instruction consisted of the image numbers associated with the initial and final frame viewed each student hour, as well as the total number of errors committed during the period of exposure. It should be noted that, on occasion, the records indicated a net loss of progress after an hour of programmed instruction -- the case in which the student "washed back" to the beginning of a section at the end of the study period. There was no way to record the number of "wash-backs" assignable to any student; consequently, the error rates computed lack, to some degree, direct comparability from student to student.

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*TM

1. Two AutoTutor Mark II's and "First Year Electronics" programs were purchased with NDEA support from U. S. Industries, Inc., Educational Science Division, Goleta, California. The program is a revised form of an electronics program prepared for the U. S. Air Force under contract No. AF 33(616)-6983 CPFF.

The students studied from locked machines for the entire period preceding the mid-semester examination. Following this examination, the machines were unlocked so that the control exercised by the test sequences could be by-passed at the students' discretion. For this reason, student error rates and rates of progress through the program were computed from data collected prior to the mid-semester examination.

Curriculum similarity between the programmed course and the lecture-presented materials was considered to be extremely high. The lecturer studied the program during the summer preceding the experiment and organized his lecture notes so as to reflect the same order of presentation and coverage of material as contained in the programmed course. Fortunately, very little reorganization of lecture material was required to achieve almost complete content similarity for the two instructional approaches.

All groups were administered three criterion examinations, the first after six weeks, one at the mid-semester point and the third at the end of the semester. Test items were prepared from instructional objectives characterizing both the programmed and the lecture approaches, as well as the homework assignments from the textbook (Jackson, 1959). The tests were prepared by the lecturer and the project director, both electronics instructors at Bakersfield College. All subjects were tested at the same time and place in a single administration of each test. As a check on the randomization procedure, each subject was administered the Ohio State Psychological Test during the first week of the semester.

In addition to the intelligence and criterion measures, the Dean of Students required each subject assigned to the Machine and Optimal groups to report for a thirty-minute semi-structured interview after the ninth week of the evaluation. Results of the attitude evaluation have been reported in a paper by John Collins (1962); a copy of that portion of his report is appended hereto.

RESULTS AND DISCUSSION

Table I presents means and standard deviations for the Ohio State Psychological Test (Intelligence) and the three criterion tests administered during the study. In addition, the results of a single-classification analysis of variance, carried out separately for each test variable, is presented.

From the table it may be seen that the three experimental groups were very nearly identical in academic ability as measured by the intelligence test. The three criterion measures provided rather stable comparative statistics for each of the examination periods. Nevertheless, only the semester final examination resulted in an F-test sufficiently large to reject the null hypothesis at the .05 level of significance. Examination of the criterion test means and standard deviations associated with each of the three treatment groups strongly supports the conclusion that the Optimal group surpassed the other two groups by almost one standard

TABLE I

Treatment Group Means and Standard Deviations for Intelligence and Criterion Tests

Test Variable	Optimal Group (Programmed & Conventional Instruction) (N = 10)	Machine Group (Programmed Instruction Only) (N = 12)	Lecture Group (Conventional Instruction Only) (N = 24)	F-ratio	P
Ohio State Psychological Test	Mean = 61.70 SD = 19.5 (N = 10)	Mean = 61.08 SD = 19.4 (N = 12)	Mean = 62.09 SD = 23.6 (N = 22)		
Six Weeks Exam	Mean = 37.89 SD = 4.8 (N = 9)	Mean = 34.82 SD = 3.9 (N = 11)	Mean = 33.36 SD = 5.2 (N = 22)	3.01	< .10
Mid-Semester Exam	Mean = 19.44 SD = 3.2 (N = 9)	Mean = 17.80 SD = 2.9 (N = 10)	Mean = 16.62 SD = 3.2 (N = 21)	1.89	NS
Final Semester Exam	Mean = 46.11 SD = 7.7 (N = 9)	Mean = 42.89 SD = 6.6 (N = 9)	Mean = 39.05 SD = 7.2 (N = 19)	3.38*	< .05

* $F_{(.05;\ df = 2,\ 34)} = 3.30$

deviation throughout the semester. Not surprisingly, the Machine and Lecture groups did not produce sufficiently different criterion test performance to justify statistical treatment beyond that provided by the F-tests performed on all three groups.

It should be pointed out that the material tested in the three criterion examinations was contained in the first 3,478 frames of the programmed course. Students studying from the programs did not realize this, of course, and continued into the more advanced sections of the program. The lecturer also completed the basic, first semester DC material prior to the end of the semester. Unfortunately, the two courses diverge, significantly, in their treatment and organization of AC instruction. As a result, students receiving both programmed and conventionally presented instruction covered more material than that included in the criterion examinations. The average time required to complete the programmed instruction by the Machine and Optimal students was 37.8 hours. Lecture students attended an average of 49.5 hours of lecture, adjusting for absences. It is not intended to imply that the automated instruction resulted in a time saving. Subtracting the hours of lecture pertaining to material beyond the basic DC requirements, as well as lecture hours associated with DC concepts not contained in the program (e.g., Thévanin's and Norton's Theorems), it is estimated by the electronics instructors that the programmed instruction required approximately the same average student study time as required by the lecture approach.

A significant observation pertains to the characteristic study behavior of students assigned to the teaching machine. Students quickly realized that the device permitted extremely precise note-taking. Obviously, the relevant laws, concepts and illustrative circuits could be copied in exact detail for purposes of review prior to examinations. Although this behavior resulted in an appreciable reduction of student progress rates through the programmed material, it may have increased both the initial learning efficiency and the review effectiveness. It is a significant by-product of the programmed approach if such an increase in note-taking efficiency is indeed related to an increase in criterion performance. The area of student study behavior with programmed learning materials poses several excellent research hypotheses.

Table II presents intercorrelations within the groups, for the experimental variables. All correlations are Spearman Rank Order correlations, selected because of the small group N's and an inability to specify population parameters for most of the variables studied. The Total Criterion score for each subject consisted of the total of his correct responses summed over all three criterion tests. Total Criterion scores were used in the correlation analysis, as the individual criterion test reliabilities were unsatisfactory. In fact, the Spearman-Brown corrected reliability coefficient for randomized halves of the Total Criterion measure was only .70.

From Table II, it may be seen that academic intelligence, criterion performance and individual error rates on the programmed materials are significantly intercorrelated. Error rates appear to be strongly related to

criterion performance, while the relationship between intelligence and the Total Criterion measure would not appear to differ in degree with that typically reported between intelligence tests and college achievement measures. Surprisingly, individual progress rates on the programmed materials were not, with one exception, significantly correlated with any of the other variables. Within the Optimal group, error rate correlated negatively with progress rate: $r = -.60$, $p \leqq .05$. The relationship did not hold for the Machine group, however -- nor did any of the five other progress rate correlations achieve significance. In general, progress rates appeared to be dictated by personality variables rather than intelligence-related variables. Slow students were often compulsive, overly cautious, high achievement students; while other students, advancing more rapidly through the programmed material, were sometimes apt to let the program "run away with them", resulting in less complete mastery of the subject matter.

TABLE II

Rank Order Correlations Among Experimental Variables Within Optimal, Machine and Lecture Groups

Variable	Group	Total Criterion Measure (Optimal / Machine)	Total Criterion Measure (Lecture)	Progress Rate (Optimal / Machine)	Progress Rate (Lecture)	Error Rate (Optimal / Machine)	Error Rate (Lecture)
Ohio State Psychological Test	Optimal	.46	.40*	.38	.11	-.68*	-.46*
	Machine	.47		-.48		-.53	
	Lecture		.49*				
Total Criterion Measure	Optimal	-		.28	.06	-.63*	-.70*
	Machine			-.22		-.81**	
Progress Rate	Optimal	-		-		-.60*	-.20
	Machine					.17	

* .05 level of significance
** .01 level of significance

CONCLUSIONS

1. The Optimal group, receiving two complete instructional presentations, performed, on the average, almost one standard deviation higher than the average performance of students receiving either programmed or conventional instruction alone. This increase in test performance was of statistical and practical significance.

2. No statistically significant differences in achievement between the Machine and Lecture groups resulted. Apparently, the programmed instruction, supported by normal laboratory instruction and homework assignments, can communicate the curriculum objectives at least as well as conventional lecture instruction in the course investigated.

3. Academic intelligence, as measured by the Ohio State Psychological Test, appears to predict achievement resulting from automated instruction with about the same degree of success as it predicts achievement from conventional instruction.

4. Individual error rates, criterion performance and intelligence are significantly intercorrelated. Individual progress rates, however, do not appear to be correlated with intelligence related variables. The investigators suggest that personality variables account for much of the unpredictable variance in student progress rates.

5. No evidence of time saving associated with the programmed instruction appears to have resulted. It was hypothesized that note-taking behavior on the part of students studying from the programmed materials may have resulted in a decrease in progress rates offset by an increase in learning efficiency.

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APPENDIX

STUDENT ATTITUDES TOWARD THE USE OF TEACHING MACHINES*

*The section reproduced herein, with permission of the author, was selected in its entirety from "An experiment in the use of teaching machines at Bakersfield College", by John J. Collins, Dean of Students, Bakersfield College. The article has been submitted to the Junior College Journal for publication.

March 1962

STUDENT ATTITUDES TOWARD THE USE OF TEACHING MACHINES

During the fall semester, 1961-62, at Bakersfield College, there were twenty-two students assigned to programmed instruction in the basic electronics course. They were all expected to spend a minimum of three hours a week on the AutoTutor. These students were all interviewed by the writer after the conclusion of the first nine-week grading period. All of the interviews were carried out within a two-week period.

The intent of these interviews was to determine how the students felt about programmed learning; consequently, the interviews were not strictly structured.

Since it is difficult to report objectively on the results of these interviews, it is felt that an anecdotal account of the general student reaction to the use of teaching machines is in order. In general, the comments were overwhelmingly favorable.

1. Of the twenty* students interviewed, only one stated that he did not like the experience of trying to learn by machine and hoped he would be transferred back to the traditional system at mid-term.

2. In general, the students were enthusiastic about proceeding at their own rate, and no amount of critical questioning could shake their belief that this constitutes a tremendous advantage over the teacher-paced lecture. The students remarked that their notes from the machine were far superior to any lecture notes they had ever taken -- the main reasons for which were that the machine never got "sidetracked", and they could always take the time to write down detailed notes.

3. They felt that instructors could not possibly gear themselves to meet the needs of all of their students in a lecture, and that, even though they could ask questions of a teacher and not of a machine, this is just as often a disadvantage as it is an advantage. They cited the irrelevent question and the disorganized answer as examples. It was the general feeling of these students that teachers pick out the main points for emphasis while the machine covers all of the material. Using the branching technique, as the program used does, the student cannot proceed until a certain level of understanding is reached. The students mark this a great advantage over classroom instruction where understanding is generally only assumed. They feel that the machine approach is not only more realistic, but is also a much stronger

*Two students assigned to the teaching machine dropped out of school prior to the interview period.

motivating force, since each individual knows, as he proceeds from frame to frame, that he is going to be held responsible for the material in the section test -- that if he doesn't understand adequately, he will be sent back.

4. All of the students were impressed by the machine's approach to errors. They felt that the machine was able to analyze the level of error and send the student, individually, where he needed to be. For example, a minor error in calculation might send him back one frame; a missed question on a section test might send him back over the same section or possibly down another branch to clarify understanding. This, the students felt, cannot possibly be done by a teacher except in the tutor-student relationship. These students also felt that the constant testing on every frame, as well as at the end of every section, was a stimulant to paying attention, and that this system taught one to operate "under his own power" rather than to depend on the extrinsic motivation of the teacher. Another factor here seems to be the machine's consistent and constant reviewing, even when the student has selected the right answer. The students reported that this was most helpful -- they were told why their answer was right when it was right, and why it was wrong when it was wrong.

5. Some incidental comments both favorable and critical follow:

   a. "The students who are not on the machine wish that they were." (Universal)

   b. "Guessing is a waste of time, and, even if you could cheat in this situation, you would be so certain that you would only cheat yourself that you would reject the idea." (The writer probed on the matter of cheating, and in every instance the students became a little indignant over the idea that they would bother to cheat a machine.)

   c. "I would like to meet with the teacher once a week or once every two weeks to ask questions and hear some of the questions that others are raising." (Only a few volunteered this attitude, but a number of others, when asked, indicated they would like some kind of a seminar.)

   d. "The machine has a grip on you that the teacher doesn't have." (The feeling here was that you can "wool gather" or "daydream" through a lecture,

but, in the "one-to-one" relationship of student-machine, this wasting of time was less likely, or, if you couldn't concentrate, you could walk out on the machine without having any serious repercussions.)

e. "The machine is always logical." (This view wasn't universally shared. A number of students complained of certain sections in the program and also of ambiguous questions.)

f. "A slow learner has a chance." (This attitude, when held, has a strong grip on the student. The writer feels that those students who identify themselves as slow learners have a long history of frustration in their dealings with teachers. They are condemned. A number made such comments as, "The machine never laughs at you"; "It never uses sarcasm"; and, "It never is unfair.")

g. "I do not wish to be taken off the machine at mid-term." (Nineteen out of twenty shared this attitude.)

h. "The machine doesn't permit you to go back and review." (This is true under certain circumstances. However, it is possible to have the instructor open the machine and turn the microfilm back without recording errors.)

i. "The machine counts errors -- you are always under pressure." (This attitude was commonly held, but not necessarily in a critical manner. Some students marked this as an advantage. Others complained of it.)

j. "A teaching assistant should be present and have the machine all loaded and ready to go when the student arrives for his 50-minute hour." (This was a universal complaint of the students which could be remedied by proper organization.)

k. "Maybe students need a push that the machine doesn't give. Maybe students aren't mature enough to be so much on their own. Maybe students miss the teacher." (Although these comments weren't commonly volunteered it is felt that the students miss the solidarity of the classroom situation and in particular feel the loss of not having a mature adult to guide them. As noted, only one student wanted to give up automated instruction, but the writer believes that the students feel that the machines need to be supplemented by a teacher.)

l. In response to the question, "Does the constant testing make you anxious?", the almost universal answer was negative. The students feel that the questions on every frame keep them motivated. They report that they read with more attention since they know that they will soon have to respond to what they have read.